Nanosensors for food safety applications

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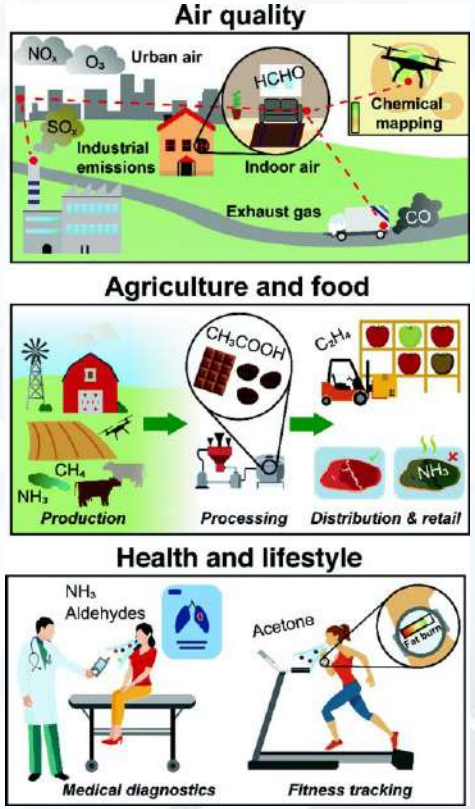
Outline

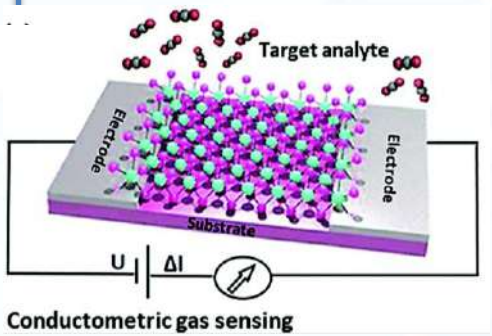
- Background: Gas sensors
- Why research on gas sensors?: The need
- Choice of sensing layer
- Research interest: Nanosensors for food monitoring
- Strategic approach
- Outputs: Ethanol detection
- Summary
- Acknowledgements

Background: Gas sensors

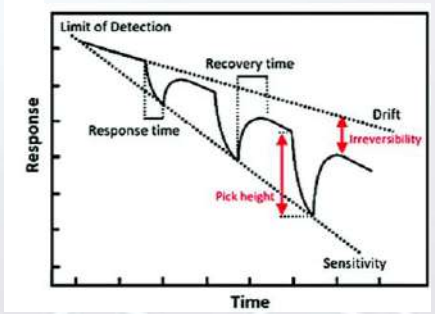
❑ Gas sensor technology



❑ Choice of material



❑ Sensor parameters



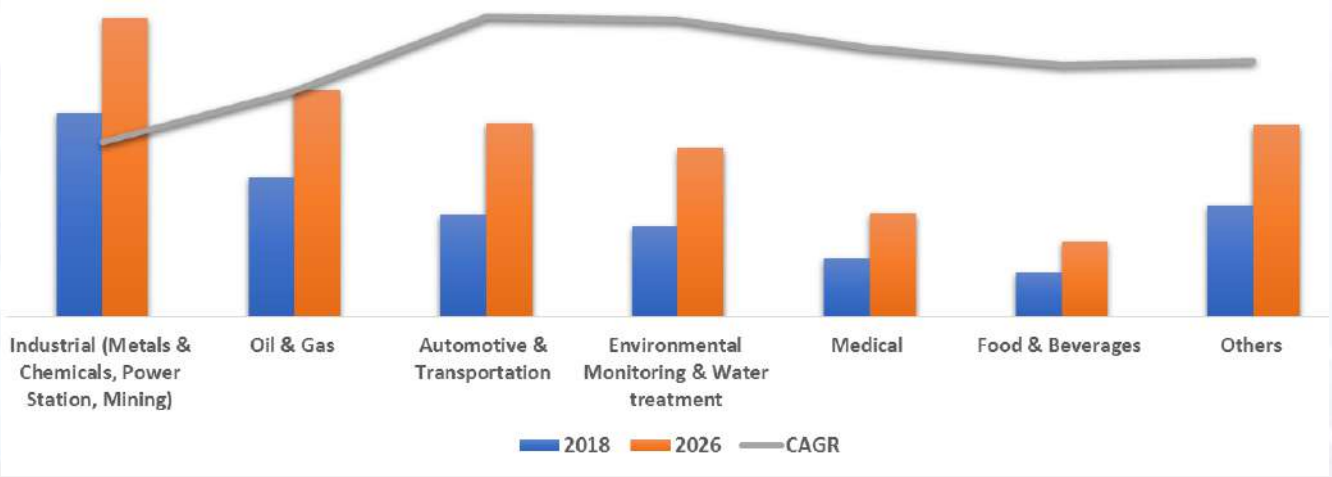
❑ Challenges

1. High operating temperatures (high power consumption)
2. Selectivity − ability to select a specific gas amid others
3. Stability − ability to reproduce the sensing characteristics over a period of time

❑ Approaches to overcome the challenges

1. Morphology engineering
2. Doping/development of heterostructures
3. Surface sensitisation with noble metals

Why research on gas sensors?: The need



[Global Gas Sensors Market Analysis by Top Companies Engineering, AMS AG, Amphenol Corporation AB, MSA Safety Incorporated, Sensirion AG and City Technology (prweb.com)]

Sensors by technology

- ❑ Solid State/Metal Oxide semiconductor
- ❑ Electrochemical
- ❑ Infrared
- ❑ Optical

Gas Sensors Market Size and Forecast

- ❑ The Global Gas Sensors Market was valued at US $939.5 million in 2018
- ❑ The Global Gas Sensors Market is projected to reach USD 1,575.9 Million by 2026, growing at a CAGR of 6.81% from 2019 to 2026

Choice of sensing layer

❑ T039

Nanomaterials

- ❑ Improved surface area and catalytic activity
- ❑ Can further be improved by morphology engineering, doping and noble metals loading

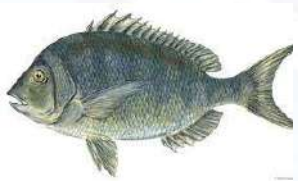
❑ Morphology engineering

❑ Noble metals loading

❑ Doping and heterostructures

Research interest: nanosensors for food monitoring

Muscle food:




- NH_3
- TMA
- H_2S
- Ethanol
- CO_2

Fruit and vegetables:


- Acetone
- Ethylene
- Ethanol

Dairy:

- Ethanol
- CO_2
- Ethylene

Grains:

- CO_2

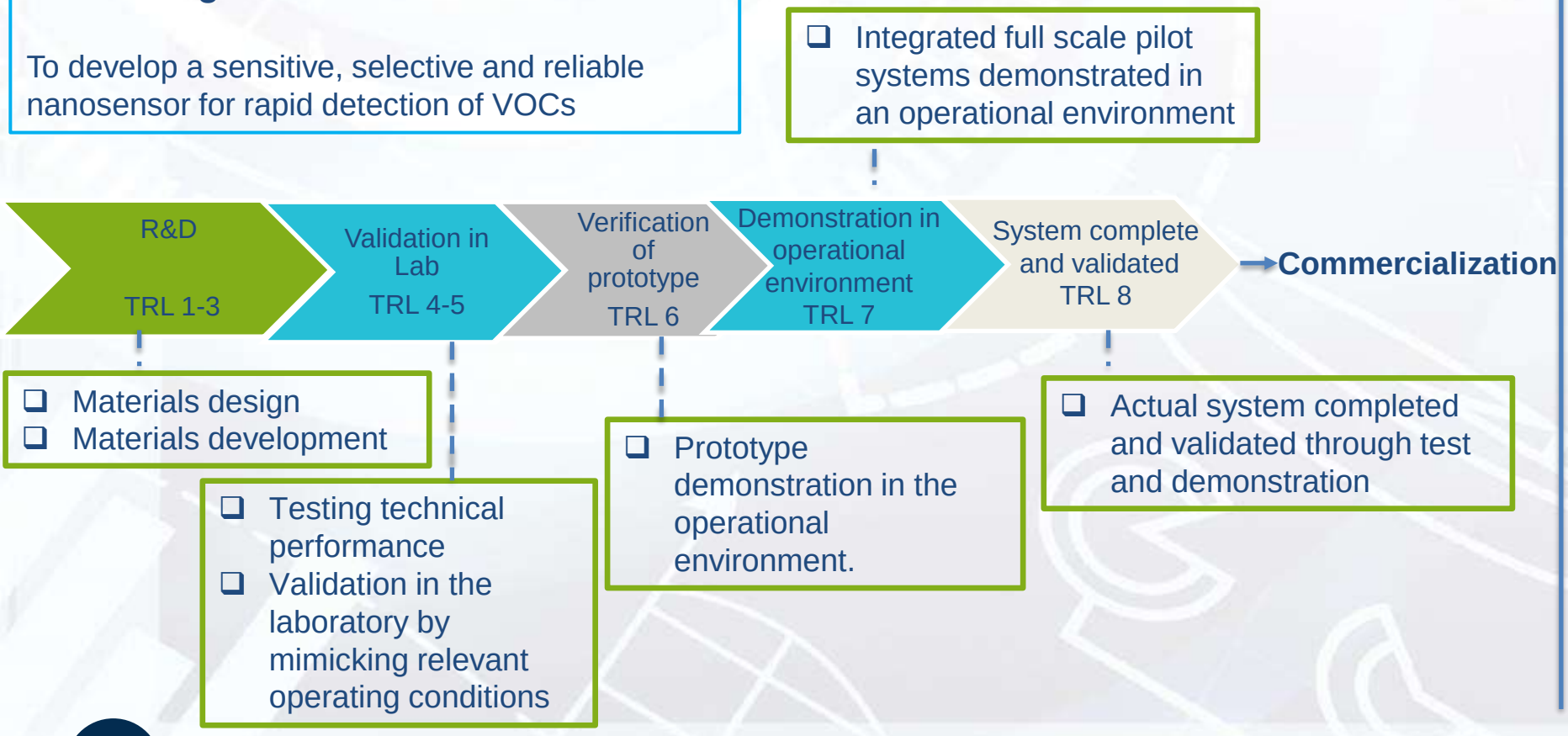
Need:

Sensitive, selective and reliable gas nanosensor for food quality status monitoring

Strategic approach

Research goal:

To develop a sensitive, selective and reliable nanosensor for rapid detection of VOCs

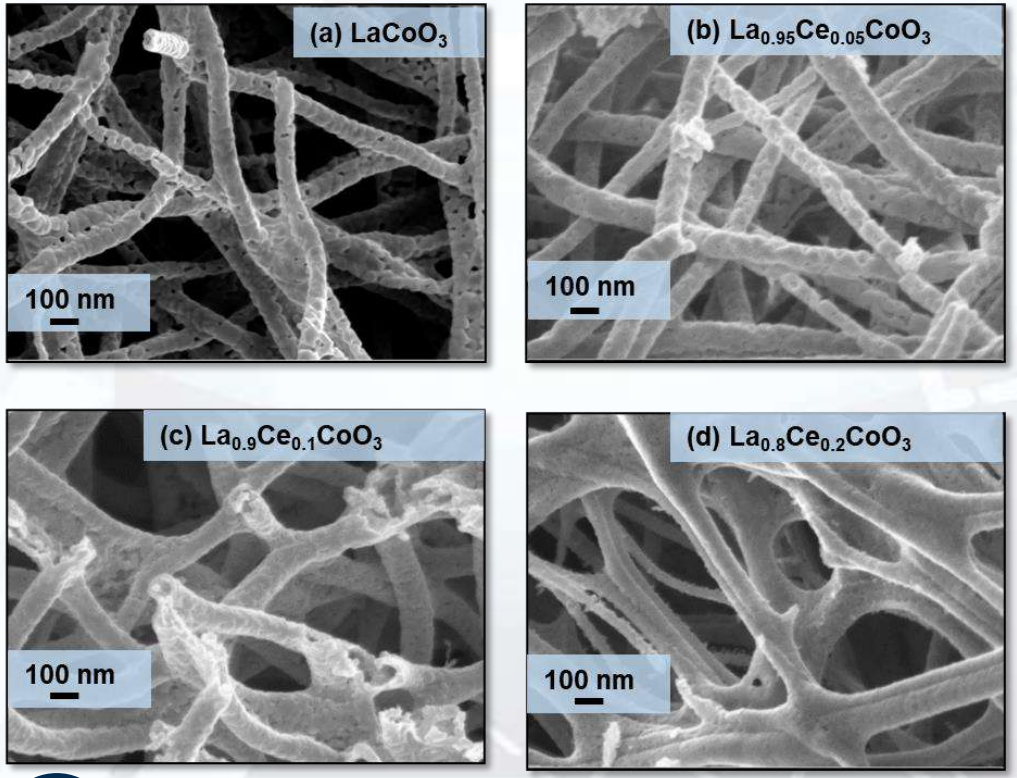


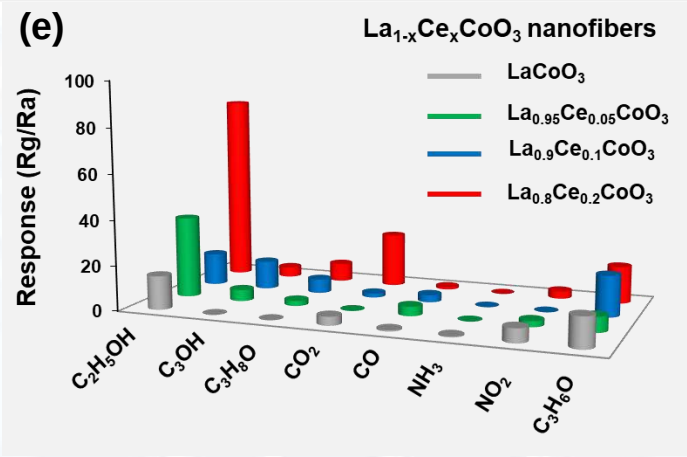
Research objectives:

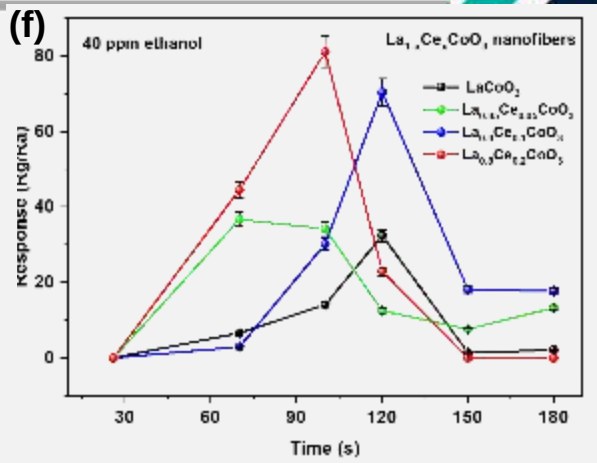
- ❑ Design nano-enabled based sensors
- ❑ Investigate the nano-enabled based gas sensors performance towards the VOCs emitted by fruit and vegetables as per application specifications
- ❑ Correlate the gas sensing performance to ripening/ spoilage of fruit and vegetables, with focus on ethanol, acetone and ethylene

Outputs: Ethanol detection

- Motivated by K. Shingange *et al*, Sensor. Actuator: B, 2020







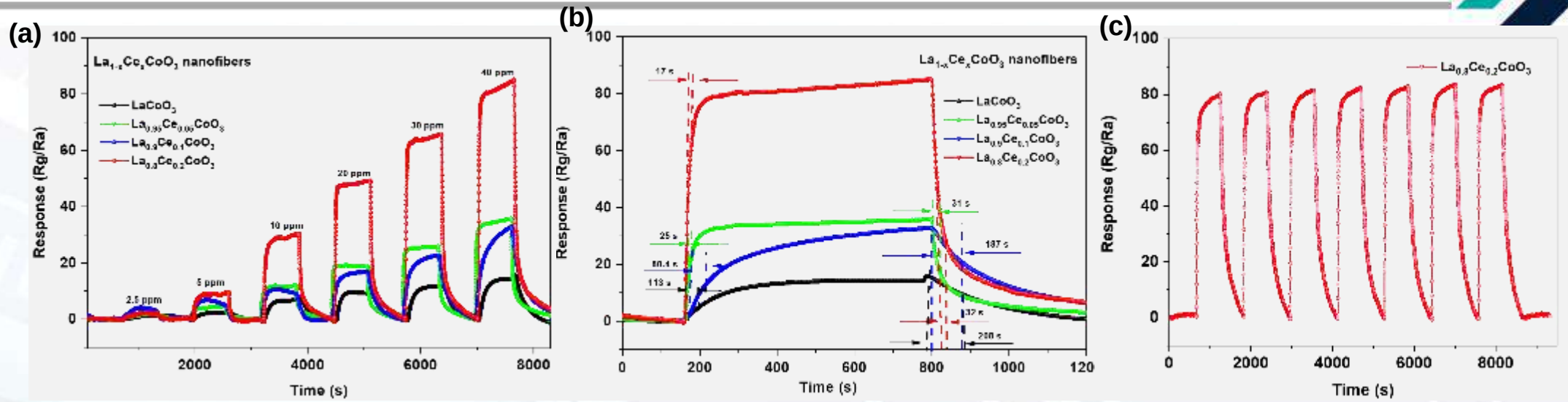
- **Selectivity ✓**
- **Temperature dependence ✓**

Sensor specifications:

- Range 2.5-40 ppm
- Ethanol selectivity
- Temperature of 100 ° C

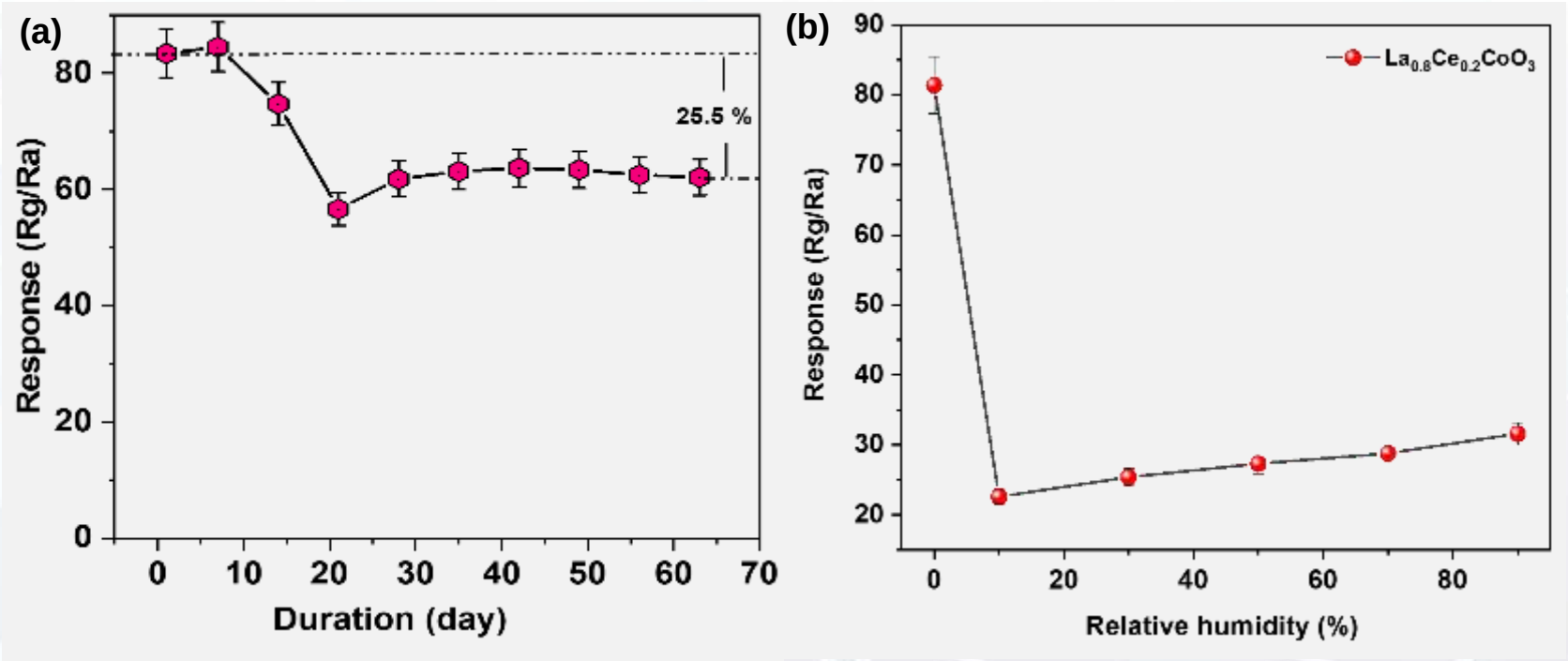
Enhanced ethanol sensing abilities of $La_{1-x}Ce_xCoO_3$ ($0 \leq x \leq 0.2$) perovskites nanofibers at low operating temperatures

Outputs: Ethanol detection continued…



- ❑ Response ✓
- ❑ Rapid response and recovery ✓
- ❑ Repeatability ✓

Outputs: Ethanol detection continued…



- ❑ Stability ✓
- ❑ Relative humidity ✓

Outputs: Ethanol detection continued…

Sensing material	T (°C)	Conc. (ppm)	Response	τ_{res}/ τ_{rec} (s)	Ref
$LaMnO_3$-SnO_2	260	100	20	6/34	[1]
Ag/Zn–$LaFeO_3$	55	100	64.2	100/20	[2]
$La_{0.75}Ba_{0.5}FeO_3$	210	500	136.1	42/40	[3]
$LaAlO_3$	350	1000	16.45	16.45/-	[4]
$LaCoO_3$	120	40	32.4	26/66	[5]
NiO@$LaFeO_3$	240	10	14.7	2/9	[6]
$La_{0.8}Ce_{0.2}CoO_3$	100	40	83.4	17/32	This work

[1] D. Chen *et al*, J. Nanopart. Res. 20 (2018) 1-10
[2] M. Chen *et al*, Adv. Mater. Interfaces. 6 (2019) 1801453
[3] J. Xiang *et al*, Mater. Chem. Phys. 213 (2018) 122-129
[4] W. Haron *et al*, Ceram. Int. 43 (2017) 5032-5040.
[5] K. Shingange *et al*, Sens. Actuators B. 308 (2020) 127670.
[6] P. Hao *et al*, Appl. Surf. Sci. 515 (2020) 146025.

Summary

- The nanofibers demonstrated great selectivity to ethanol along with the sample having the highest amount of Ce ($La_{0.8}Ce_{0.2}CoO_3$) achieving a response greater than twofold the one attained for $LaCoO_3$ at an operational temperature of 100 °C, as well as rapid response and recovery time of 17 and 32 s.
- The sensors based on $La_{1-x}Ce_xCoO_3$ nanofibers, particularly $La_{0.8}Ce_{0.2}CoO_3$, could be considered as a prospective energy-efficient material to be utilised for low levels of ethanol molecules detection in applications, such as food shelf-life monitoring in the food industry

Outlook

- Test at lower concentrations (< 1ppm)
- Include ethylene for selectivity
- Stability tests over a longer period (6 months)

Acknowledgements

- Sensors for food safety group
- Centre for Nanostructures and Advanced Materials
- Characterisation facility
- Council for Scientific and Industrial Research
- Department of Science and Innovation


THANK YOU